6.5 Fission Product Removal and Control Systems

6.5.1 Engineered Safety Feature (ESF) Filter Systems

This subsection is not applicable to the AP1000.

6.5.2 Containment Spray System

In the event of a design basis LOCA there is an assumed core degradation that results in a significant release of radioactivity to the containment atmosphere. This activity would consist of noble gases, particulates, and a small amount of elemental and organic iodine (as discussed in subsection 15.6.5.3, most of the iodine would be in the particulate form). The AP1000 does not include a safety-related containment spray system to remove airborne particulates or elemental iodine. Removal of airborne activity is by natural processes that do not depend on sprays (that is sedimentation, diffusiophoresis, and thermophoresis). These removal mechanisms are discussed in Appendix 15B.

Much of the non-gaseous airborne activity would eventually be deposited in the containment sump solution. Long-term retention of iodine in the containment sump following design basis accidents requires adjustment of the sump solution pH to 7.0 or above. This pH adjustment is accomplished by the passive core cooling system and is discussed in subsection 6.3.2.1.4.

In accordance with Reference 1, the fire protection system provides a nonsafety-related containment spray function for accident management following a severe accident. This design feature is not safety-related and is not credited in any accident analysis including the dose analysis provided in section 15.6.5. Dose reduction following a severe accident may be enhanced over the natural removal mechanisms via the nonsafety-related containment spray. Subsection 15.6.5.3.2 provides additional discussion of the natural removal mechanisms. The following subsections provide a discussion of the nonsafety-related containment spray function provided by the fire protection system.

6.5.2.1 System Description

The fire protection system provides a nonsafety-related containment spray function for severe accident management. Subsection 9.5.1 provides a description of the fire protection system including equipment and valves that support the containment spray function such as the fire pumps and fire main header. This section provides the description of the portion of the fire protection system designed specifically to provide the containment spray function.

The source of water for the containment spray function is provided by the secondary fire protection system water tank. Either the motor driven or diesel driven fire protection system pump may be used to deliver fire water to the containment spray header. The flow path to containment is via the normal fire main header as shown in Figure 9.5.1-1, sheets 1 through 3. The containment spray flow path is from the fire main extension, through the fire protection system line that penetrates containment, to the containment spray riser that connects to the fire protection system header inside containment. This riser supplies two ring headers located above the containment polar crane.

6.5.2.1.1 Valves

The containment spray flow path from the fire main header contains one normally open manual valve (FPS-V048), one normally closed manual valve (FPS-V101), one locked closed manual containment isolation valve outside containment (FPS-V050), a containment isolation check valve inside containment (FPS-V052), a normally open manual isolation valve in the spray riser (FPS-V700), and a normally closed remotely-operated valve (FPS-V701) downstream of the manual isolation valve in the spray riser.

Containment spray is initiated by first closing the passive containment cooling water system fire header isolation valve (PCS-V005) isolating the passive containment cooling water storage tank, opening the manual valves outside containment, and by opening the remotely-operated valve inside containment. The manual valves outside containment are located in valve / piping penetration room 12306. The valves are located close to the entrance door such that radiation exposures to an individual required to enter the room and align the valves would not exceed the prescribed post-accident dose limits discussed in subsection 12.4.1.8.

Valve FPS-V701 is a fail-open air-operated valve such that the containment spray flow path can be opened following a loss of the nonsafety-related compressed air system. During shutdown operations, the fire protection system header inside containment is pressurized from the passive containment cooling water storage tank for fire protection and manual isolation valve FPS-V700 is closed.

6.5.2.1.2 Containment Spray Header and Nozzles

The containment spray header consists of a single header that feeds two ring headers located above the containment polar crane. The containment spray ring headers and spray nozzles are oriented to maximize containment volume coverage. A lower ring header is located at plant elevation 260 feet, and contains 44 spray nozzles. An upper ring header is located at plant elevation 275 feet, and contains 24 spray nozzles.

The nozzles within the spray ring header are conventional containment spray nozzles utilized in past Westinghouse pressurized water reactors. The spray nozzles are selected on the basis of drop size to provide adequate absorption of fission products from the containment atmosphere.

6.5.2.1.3 Applicable Codes and Classifications

The containment spray function is not safety-related, and therefore the valves and piping in the containment spray flow path are not required to be safety-related for the containment spray function. However, the containment isolation piping and valves are safety-related (AP1000 Equipment Class B) to perform the safety-related function of containment isolation. The classification of the remaining portions of the fire header are nonsafety-related, and are classified as Class F as discussed in subsections 3.2.2.7 and 9.5.1. The containment spray header and valve, downstream of the manual isolation valve inside containment is nonsafety-related and classified as Class E. The containment spray header is classified as Seismic category II.

6.5.2.1.4 System Operation

During normal operation, the fire protection system header inside containment is isolated from the fire main header by closed isolation valves, including a locked closed containment isolation valve. The containment spray piping is therefore not pressurized during normal operation. During plant shutdown modes, personnel access to containment is required, and as such, the fire protection system standby header inside containment is pressurized by the water in the passive containment cooling water storage tank. During these modes, the manual isolation valve located between the header and the spray ring is closed to further isolate the containment spray header from the passive containment cooling water storage tank. Inadvertent actuation of the containment spray system during power operation and shutdown is not credible. Inadvertent actuation of the containment spray would require multiple failures of closed valves.

Severe accident management guidelines provide the operator with guidance to initiate the containment spray feature of the fire protection system. Operator action to open two manual isolation valves outside of containment followed by remotely opening the containment spray isolation valve within containment from either the main control room or the remote shutdown workstation will initiate the spray function. Containment spray may be terminated at any time by closing the remotely operated isolation valve within containment, or by closing any of the manual valves in the containment spray flow path outside containment. Operation of the containment spray will have no effect on the availability of the remainder of the fire protection system other than the loss of inventory from the secondary fire water tank due to the sprayed water. To preserve inventory for firefighting, the primary fire water tank is isolated during containment spray operation. Since the fire protection system operates in the active standby mode, i.e. the supply piping is kept full and pressurized, once the remotely operated isolation valve is opened the system will perform the containment spray function.

When water pressure in the fire main begins to fall, due to a demand for water from containment spray, the motor-driven pump starts automatically on a low-pressure signal. If the motor-driven pump fails to start, the diesel-driven pump starts upon a lower pressure signal. The pump continues to run until it is stopped manually.

6.5.2.2 Design Evaluation

6.5.2.2.1 Containment Coverage

The containment spray nozzles are the Lechler (SPRACO Company) spray nozzles or equivalent, which provide a drop size distribution which has been established by testing and found suitable for fission product removal. The fire protection system header provides a containment spray nozzle differential pressure of 40 psid, which fixes the drop size distribution. The mass mean drop size produced at this differential pressure is conservatively assumed to be 1000 microns.

The fire protection system header can provide the design flow rate of 15.2 gpm to each spray nozzle at a containment backpressure of 20 psig for a total containment spray flow of approximately 1034 gpm. Analyses of severe accident sequences show that containment backpressure is less than 20 psig after containment spray flow is initiated.

Figure 6.5-1 is a diagram of containment which shows the developed spray patterns for the containment spray ring headers. The overlay of the spray patterns on the containment is useful in illustrating the completeness of spray coverage in the sprayed region. Furthermore, as discussed in reference 2, there is significant momentum exchange between the spray droplets and the closed air volume of the containment, which provides far greater mixing within the sprayed region than the idealized spray patterns would indicate. Therefore, even though small areas of the sprayed region are not directly sprayed by the developed spray patterns, the sprayed region of the containment is well-mixed.

The sprayed regions of containment include the region of containment above the operating deck, and the refueling cavity, which is open at the operating deck. The total free volume of the sprayed region is approximately 1.7×10^6 cubic feet which represents approximately 84% of the total containment free volume.

6.5.2.2.2 Aerosol Removal Effectiveness of Sprays

The removal of aerosol activity from the containment atmosphere by sprays is simply described by:

$$C_t = C_o e^{-\lambda t}$$

where:

C_t = concentration of aerosols at time "t"

C_o = initial concentration of aerosols

λ = aerosol removal coefficient for sprays (hr^{-1})

t = elapsed time (hr)

However, to fully model the removal of aerosols from the containment atmosphere in a severe accident, the analysis also needs to take into account mixing between the sprayed and unsprayed regions and the rate of release of activity from the core into the containment atmosphere.

6.5.2.2.3 Aerosol Removal Coefficient for Sprays

The aerosol removal coefficient for sprays is calculated by the following equation from the Standard Review Plan (Reference 2):

$$\lambda = 3hfE / 2Vd$$

where:

h = average spray drop fall height (ft)

f = spray flow rate (ft^3/hr)

E = collection efficiency

V = volume of the containment exposed to sprays

d = average spray drop diameter (ft)

Reference 2 identifies a value for E/d of 10 m^{-1} (3.05 ft^{-1}) as being conservative until the air concentration is reduced by a factor of 50. Using this together with a nominal spray fall height of 125 feet and a nominal flow rate of 1000 gpm (8022 ft^3/hr), the aerosol removal coefficient for the containment sprays is approximately 2.7 hr^{-1} in the sprayed volume. This spray removal coefficient is significantly greater than that associated with the natural removal mechanisms assumed in the design basis analysis (see Appendix 15B) and would enhance dose reduction following a severe accident.

The decontamination factor (DF) that would be achieved at any point in time is dependent on the timing of spray operation. Additionally, the continuing release of activity must be factored into the determination of DF (i.e., the DF would be based on the integrated activity release to the containment at a point in time, not on the amount of activity present in the containment atmosphere at the time spray operation is initiated). After a DF of 50 is reached, the value of E/D would be reduced by a factor of ten (Reference 2) and the aerosol removal coefficient would also be reduced by the same factor to a value of 0.27 hr^{-1}. Based on an assumed spray actuation shortly after the onset of core melt and a nominal spray duration of three hours, the DF of 50 would not be reached until after spray operation was terminated.

6.5.3 Fission Product Control Systems

The containment atmosphere is depleted of elemental iodine and particulates as a result of the passive removal processes discussed in DCD Appendix 15B. No active fission product control systems are required in the AP1000 design to meet regulatory requirements. The passive removal processes and the limited leakage from the containment of less than L_a as defined in the Containment Leakage Rate Testing Program, result in doses less than the regulatory guideline limits. (See subsection 15.6.5.3.)

6.5.3.1 Primary Containment

The containment consists of a freestanding cylindrical steel vessel with ellipsoidal heads. The containment structural design is presented in subsection 3.8.2.

The containment vessel, penetrations, and isolation valves function to limit the release of radioactive materials following postulated accidents. The resulting offsite doses are less than regulatory guideline limits. Containment parameters affecting fission product release accident analyses are given in Table 6.5.3-1.

Long-term containment pressure and temperature response to the design basis accident are presented in Section 6.2.

The containment air filtration system may be operated for personnel access to the containment when the reactor is at power, as presented in subsection 9.4.7. For this reason, the radiological assessment of a loss-of-coolant accident assumes that both trains of the air filtration system are in service at the initiation of the event. The isolation valves receive automatic signals to close from diverse parameters. The valves are designed to close automatically as described in subsection 6.2.3.

Containment hydrogen control systems are presented in subsection 6.2.4.

6.5.3.2 Secondary Containment

There is no secondary containment provided for the fission product control following design basis accident.

The annulus between containment and shield building from the elevation 100′-0″ to the elevation 132′-3″ acts as a holdup volume to limit the spread of fission products following severe accident. Most containment penetrations are located within this holdup volume. It is served by the radiologically controlled area ventilation system (VAS) described in subsection 9.4.3. Isolation dampers are provided to reduce the air interchange between the holdup volume and environment. Fission product control via holdup within the annulus is considered in severe accident dose analysis but excluded from consideration for design basis accident dose evaluations presented in Chapter 15.

6.5.4 Combined License Information

This section has no requirement for additional information to be provided in support of the Combined License applications.

6.5.5 References

1. SECY-97-044, "Policy and Key Technical Issues Pertaining to the Westinghouse AP600 Standardized Passive Reactor Design," June 30, 1997.

2. NUREG-0800, Section 6.5.2, Revision 2, "Containment Spray as a Fission Product Cleanup System."

Table 6.5.3-1

PRIMARY CONTAINMENT OPERATION FOLLOWING A DESIGN BASIS ACCIDENT

Type of structure	Freestanding cylindrical steel vessel with ellipsoidal heads
Containment free volume (ft^3)	2.06×10^6
Design basis containment leak rate	0.10% containment air weight per day

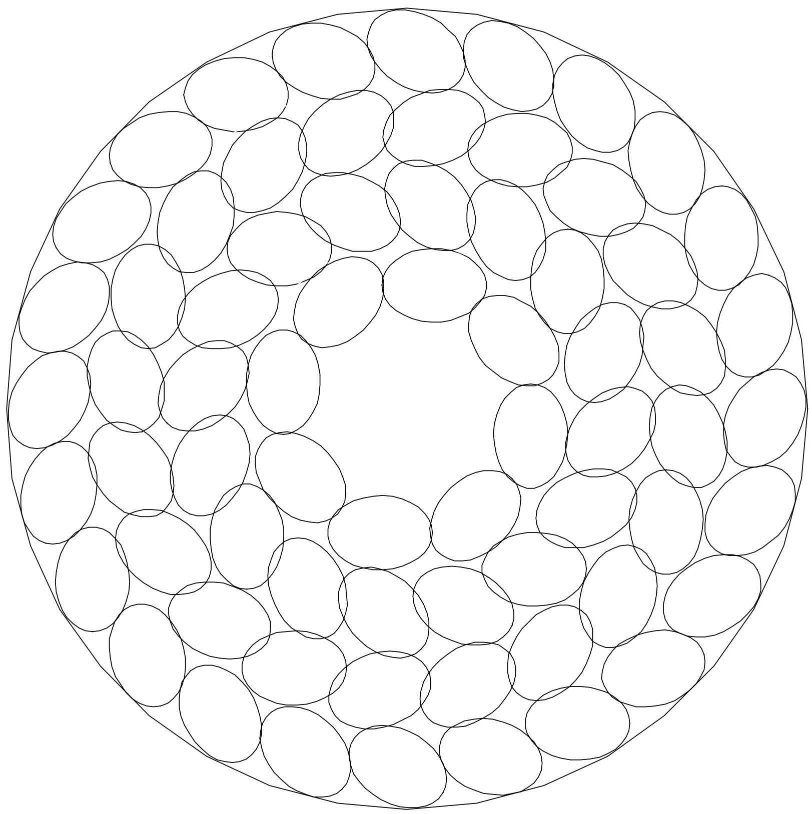

Figure 6.5-1

Containment Spray Coverage at Operating Deck